Electro-Mechanical Gripper Robot

Minor Project

Submitted in partial fullfillment of the requirement of the degree of Bachelor's of Engineering

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CERTIFICATE

This is to certify that Utkarsh Kamerikar, Shashank Singh Parihar, Sachin Gupta, Mihir Shrivastava, Shailesh Marko, Ritwik Jain of 3rd year (6th semester) have successfully completed their major project on "Electro-mechanical Gripper Robot" in the partial fulfilment of their bachelor's of engineering in Mechanical Engineering.

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ACKNOWLEDGEMENT

For the accomplishment of this project work, expression and words run short for us, to convey our sincere gratitude towards many individuals. We are eternally grateful to Prof. A.C Tiwari `inspiration and motivation throughout the project and under whose guidance we were solely able to complete our project. Apart from this, we would also like to express our deepest concern towards Dr. Sudhir Singh Bhadauria of UIT-RGPV, for providing such a studious and healthy atmosphere which encouraged us consistently on focusing upon our task. Never the less, we are greatly obliged to have the faculties of our Mechanical Department with us, who have constantly supported and guided us with new and better ideas.

Finally, we would like to extent our sincere thanks to all those who helped us and were involved in this project knowingly or unknowingly.

CANDIDATE'S DECLARATION

We hereby declare that the Major project work is being presented in the report entitled "Electro-Mechanical Gripper Robot" is in the partial fulfilment for the award of the degree of Bachelor of Engineering in Mechanical Engineering. The work has been carried out at University Institute of Technology, Rajiv Gandhi Proudyogiki Vishwavidyalaya (UIT-RGPV), Bhopal and is an authenticated record of our own work carried out under the guidance of Mrs. Pratiksha Shrivastava, Faculty at Department of Mechanical Engineering.

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ABSTRACT

Since the humanity was born, hands have been the most essential parts of the body for our interaction with the environment. It would make no sense to receive a huge amount of information through the senses and processing it incredibly fast in the brain if then you cannot perform consequently. And just as human hands are the organs of human manipulation, if we make the comparison with a robot, their prehension tools are what is commonly called “grippers”.

As the end of the kinematic chain, is usually the only part in direct contact with the work piece as well. It can be defined as: Grippers: “Subsystems of handling mechanisms which provide temporary contact with the object to be grasped. They ensure the position and orientation when carrying and mating the object to the handling equipment. Prehension is achieved by force producing and form matching elements.

The term “gripper” is also used in cases where no actual grasping, but rather holding of the object as e.g. in vacuum suction where the retention force can act on a point, line or surface.” Definition from (1).

Human hands are capable of grasping objects of an enormous range of sizes, shapes and weighs. This is a difficult achievement for a robot gripper and it is only possible due to the greatest variety of designs for either specific tasks or general ones than can be found nowadays. Matching the necessity of a robot to be able to pick up objects with the increasing trend of DIT (Do it yourself), a modular robot with a gripper module will encourage people to build their own robot learning in different fields as mechanics or programming while enjoying their time.

The main goal of this Project is the design, manufacturing and construction of a robot’s gripper.

However, this is not the only goal, this project has other secondary goals:

- It could be a guide for everyone who wants to introduce in the world of the robotic and robot’s design.

- Another goal is to create a structure easy to insert changes and improvements inside it.

- One personal goal is to pass successfully my individual project and to learn a lot about robots and design.

- It could be great to help people with health problems to take objects that they can’t take.

- We can test this gripper in a robot’s arm and use it like part of the robot.

- This kind of robot’s grippers could be used in the companies and they would have the next advantages for the companies:

  ○ Increased productivity. o Quality improvement. o Increased speed: It is due to the automatic repetition of the movements of the robot with speed optimization.

  ○ High uptime without failure. o Reduced maintenance. o Substantial optimization of the employment and equipment that runs the machine. o Rapid return of the investment.

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INTRODUCTION

Our Project consists in the mechanical design of a robot's gripper. This gripper is composed of two servomotors that allow the movement of the wrist and the movement of the grippers. Due to these two movements, we would be able to take every object we want.

¿Why we choose this individual project?

In our opinion, the world of the robots is the future. In the last years, the demand of robotic products is increasing a lot. This is because with the robot, we can reduce the time of producing objects, we can be more precise, more efficient… The use of robotics provides the following advantages:

- Improves considerably the safety of the company: A robot can perform some activities that are dangerous for the human like handle potentially hazardous products, manipulate heavy loads…
- Allows the possibility of doing many different activities: A robot can be programmed to do a lot of different kind of activities. This increases his profitability.
- Allows the realization of optimum quality jobs: The precision of a robot is better than human's precision
- The level of incidents is very small: We must only to do a basic maintenance of the robots to keep them running smoothly.
- Increases the productivity of the company.
- The efficiency of the company is higher.

• With the robotic, humans have been able to devote their time improving the quality of life applying the robots to do hard works that humans did before of this discovery.

• One of the most important things of the robotic for me is that it can be used to help disabled people ant make the life of this people much better. Because of all of these reasons, we are very interesting in this world and this project allows me to start with the design of the robots. In my case, my project is only a mechanical design but we think is a good beginning to introduce

Since the humanity was born, hands have been the most essential parts of the body for our interaction with the environment. It would make no sense to receive a huge amount of information through the senses and processing it incredibly fast in the brain if then you cannot perform consequently. And just as human hands are the organs of human manipulation, if we make the comparison with a robot, their prehension tools are what is commonly called “grippers”. As the end of the kinematic chain, is usually the only part in direct contact with the work piece as well. It can be defined as:

Grippers: “*Subsystems of handling mechanisms which provide temporary contact with the object to be grasped. They ensure the position and orientation when carrying and mating the object to the handling equipment. Prehension is achieved by force producing and form matching elements. The term “gripper” is also used in cases where no actual grasping, but rather holding of the object as e.g. in vacuum suction where the retention force can act on a point, line or surface*.”

Human hands are capable of grasping objects of an enormous range of sizes, shapes and weighs. This is a difficult achievement for a robot gripper and it is only possible due to the greatest variety of designs for either specific tasks or general ones than can be found nowadays.

Matching the necessity of a robot to be able to pick up objects with the increasing trend of DIT (Do it yourself), a modular robot with a gripper module will encourage people to build their own robot learning in different fields as mechanics or programming while enjoying their time.

BACKGROUND

The grippers' world is as extended as one can imagine and before starting the design is essential to know more about the existing types and what are they used for to make sure that the right one is chosen.

Classification of grippers by gripping methods :-

To deal with the different tasks that an end-effector is in charged, grippers use diverse methods that can be categorized in the four following main groups.

- Impactive gripper. It is a mechanical gripper where the prehension force is achieved by the impact against the surface of the object from at least two directions. Are the most widely used in the industry for picking rigid objects using, for example, clamps or tongs.
- Ingressive gripper. It consists in the penetration of the work piece by the prehension tool. It can be intrusive when it literally permeates the material, for example pins, needles and hackles and on the contrary it can be non-intrusive when using other methods as hook and loop, for example Velcro. They are commonly used with flexible objects as textiles.
- Astrictive gripper. Direct contact is not needed at the beginning of the prehension and the binding force can take form of air movement for vacuum suction, magnetism or electroadhesion and it is applied in one single direction. This gripping method can only acquire particular objects: non-porous and rigid materials are required for the vacuum suction, for magnetoadhesion ferrous materials are needed and electroadhesion is only useful for light sheet materials and micro components.
- Contigutive gripper. The surface of the object and prehension means must make direct contact without impactive methods in order to produce the grasping force from one direction. Depending on the kind of force used the contigutive grippers can be classified in chemical adhesion as glue, thermal adhesion as freezing or melting and surface tension as capillary action.

Once all the gripping methods have been presented, the most suitable for picking the ten daily objects can be chosen. Taking into consideration that not all the items are metallic, light sheet or non-porous, the astrictive method can be discarded. In the same way, as the ingressive one only works with a few of them as the teddy bear because it is made of textile, it is definitely not the best option. Neither the contigutive gripper is a good choice due to the particularities of the method. In conclusion, the best choice is using an impactive gripper because it is able to grasp all the objects mentioned with their versatility of shapes and materials.

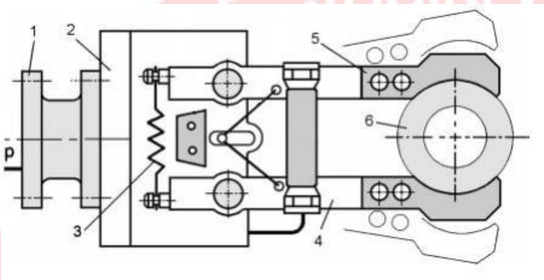
Impactive grippers (our FOCUS)

Mechanical grippers are the most frequently used in the industry field due to its great variety of applications. They may possess between two and five fingers usually with a synchronously movement. They require extensive or simple mechanisms related with the physical effects of classical mechanics as the amplitude of the friction cone between the two contact surfaces.

The complexity of the gripper lies partly in the degrees of freedom, understanding it as the required number of independent actuators that are needed for a completely defined motion of all links. The simplest one only requires one actuator but the number of degrees of freedom grows with the difficulty of the task to perform.

Parts of end-effector

An impactive gripper normally consists of drive chain placed in the gripper housing and the kinematic chain formed by the fingers that go from the housing of the gripper to the jaws. They are which are actually in contact with the work piece. All that parts are depicted in the Figure 3.



1 - Flange
2 - Gripper housing
3 - Tension spring
4 - Gripper finger
5 - Gripper jaw
6 - Workpiece

Kinematics

Figure : Parts of the en-effector of an impactive gripper (1)

The shape that the fingers must have for a determined purpose is determinate by studying the kinematics of the mechanism. There is a huge diversity of designs for the kinematic chain in order to transform rotational or translational motion into a particular jaw motion. Focusing in that, grippers can be distinguished between:

- **Parallel motion** (Jaws can follow whether a curve or lineal trajectory but always remaining parallel, i.e. without rotate)
- **Rotational motion** around a fixed point
- **General planar motion** of the jaws, for example rotation around a not-fixed point.

It is essential to know the transmission ratio of the kinematic chain to control the jaw travel from the motor motion. The jaw position can only be controlled by knowing the position of the actuator needed. This relation is reflected in the gripper stroke characteristic curve that gives the position and orientation of the jaw for each position of the actuator.

Knowing the dependence of the gripping force and the torque in the motor is also important when selecting the gripper mechanism or even the appropriated motor, at least to make sure that it is capable to do the force that is required.

Drive chain

The first component of the drive chain is always the motor which is the responsible for providing movement from electric power. There are several different types of motors in the market and for the right choice is necessary to balance their characteristics with the necessities as the accuracy in the control of the position or the maximum torque provided. The following motors may be suitable:

- **Stepper motors:** brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller). Application in low-cost systems.

- **Servo motors (synchronous motors):** rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. Application when sensitive force and position regulation is required.
- **Linear motors:** an electric motor that has had its stator and rotor "unrolled" so that instead of producing a torque (rotation) it produces a linear force along its length. Applicable to proportional operation at high speeds.
- **Piezoelectric drives:** electric motor based upon the change in shape of a piezoelectric material when an electric field is applied. Applicable for extremely light objects and high speed handling. Their reliability and lifetime is very long but the achievable stroke is limited.

The motor is attached to the guidance gear which brings the motion to transmission gears. The second ones are used for transferring the movement from one place to another or to reduce its angular speed and finally moving the fingers.

Contact methods

The design of the jaws is totally determinant for a proper prehension because it is responsible of the distribution of the grasping force and it must be taken into consideration to ensure the stability.

The movement of an object in the three dimensions of space can be disaggregated in 6 velocities corresponding to rotation and translation around the three axes. The contact between the work piece surface and the gripping area of the jaw restrict a specific number of those velocities (also called degrees of freedom, k). An object will only be completely subjected when none of their velocities are possible.

Figure 4 illustrates different ways of restricting *k* degrees of freedom for a cuboid, cylinder and sphere. For impeding one velocity only one point of contact is needed, for two a beeline or two points of contact are necessary and any other planar contact method will restrict three velocities.

The active surface of a gripper is what actually is in contact between the jaw and the object

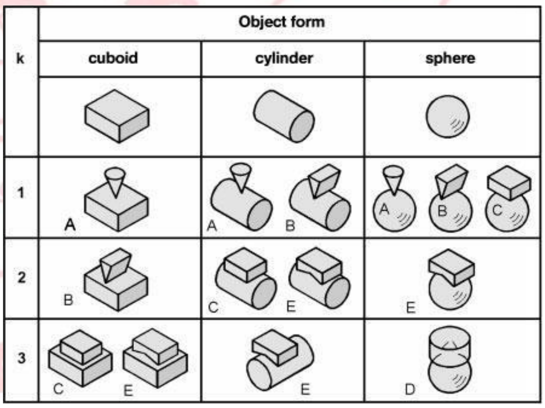


Figure : Shape of the jaw depending on the object form and the number of degrees of freedom that it restricts (k) (1)

and it is related to the geometric shapes used in the designs of jaws. It is designated as: A point contact, B line contact, C surface contact, D circular contact, and E double line contact.

Besides the importance of the total retention of the work piece, the stability of the prehension must also be ensured by the compensation of all the forces and moments on the object. Misalignment of grasped components should not be possible as a result of their weight or inertia.

A reduction in the gripping force with an improvement of retention stability at the same time is possible enlarging the active surfaces or increasing them in number by using more fingers or more adequate profiles. Figure 5 show some examples of the combination between one to three fingers and one, two or multi-point of contact.

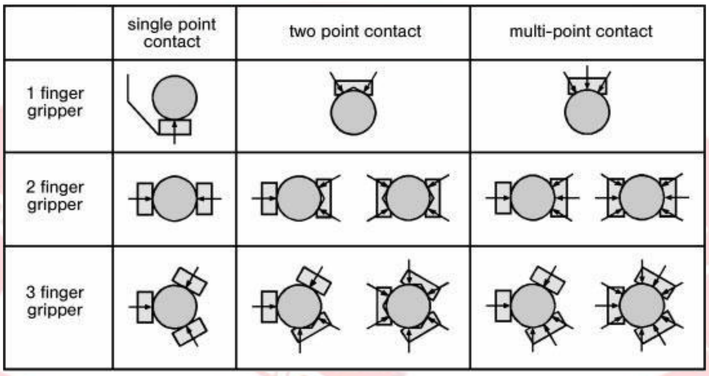


Figure 5: Distribution of the prehension force depending on the number of points of contact. (1)

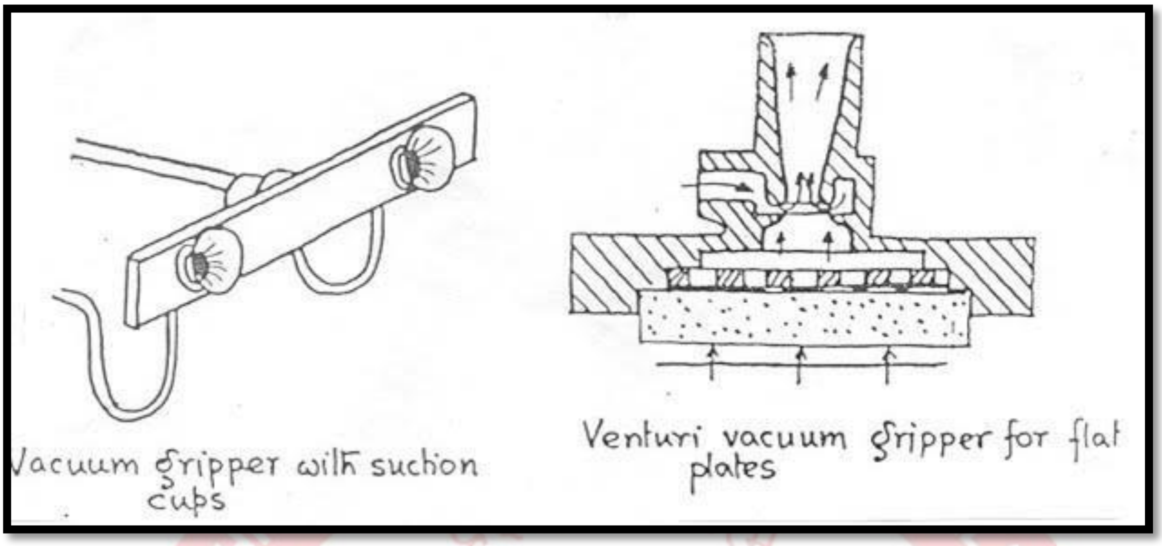
Selection of our gripper

Before starting my design of the robot's gripper, I was investigating about the current types of grippers that you can see in the market. After this investigation I discovered that there are four kinds of grippers classified according to his way of grip:

1. **Pressure gripper:** This kind of gripper is used for pieces that can be pressed by the gripper without being deformed.

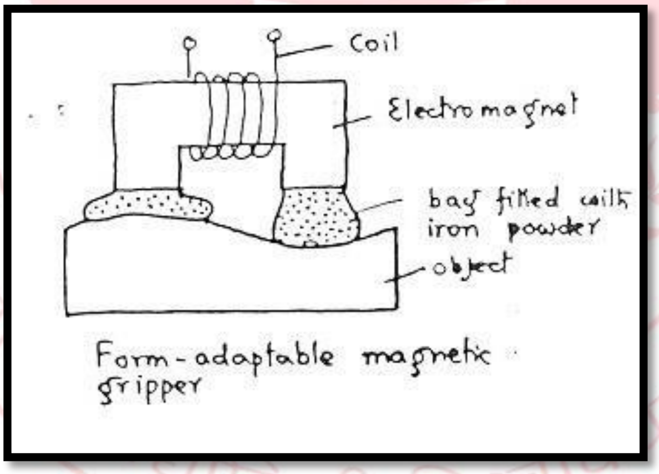
2. **Coupling gripper:** This kind of gripper is used for pieces of big dimensions that can't be pressed by the gripper.

3. **Vacuum gripper:** Vacuum grippers are used in the robots for grasping the non – ferrous objects. It uses vacuum cups as the gripping device, which is also commonly known as suction cups. This type of grippers will provide good handling if the objects are smooth, flat, and clean. It has only one surface for gripping the objects. Most importantly, it is not best suitable for handling the objects with pores.



[1] – Example of a vacuum gripper

4. **Electromagnetic gripper:** Magnetic grippers are most commonly used in a robot as an end effector for grasping the ferrous materials.

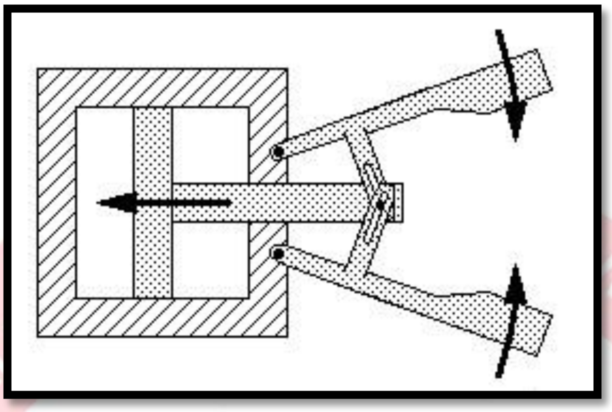


[2] – Example of a electromagnetic gripper

Because we want to build a cheap gripper and the type of pieces which normally we will take (pieces that we can press and non ferromagnetic), I selected the first kind of gripper, **the pressure gripper**.

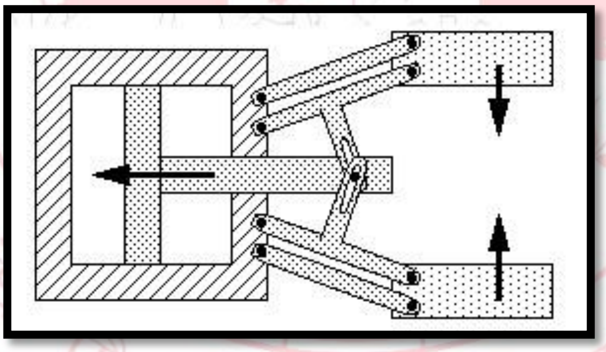
The next step was to select the type of movement that we want for our gripper. I had two type of gripper according to its movement:

1. **Rotation movement:** As we can see in the following picture [3], the gripper is based on a rotation movement to take the objects.



[3] – Example of gripper with rotation movement

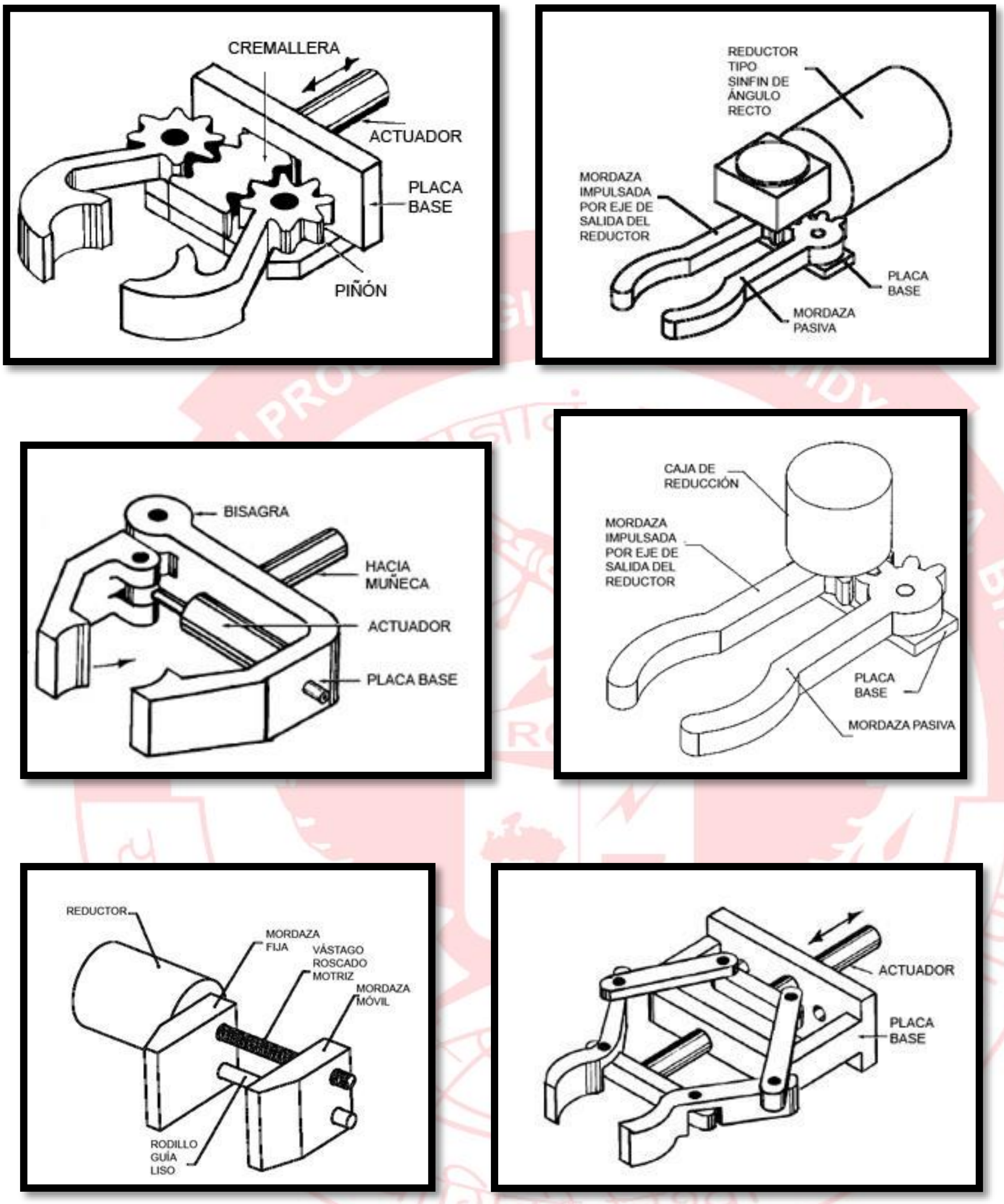
2. **Translation movement:** As we can see in the following picture [4], the gripper is based on a translation movement to take the objects.



[4] – Example of gripper with translation movement

In my opinion, the best gripper's choice was **the translation movement**, because is easier to calculate the distance where we have to put the gripper to take the object and I thought that it was the best way to grab strongly the objects.

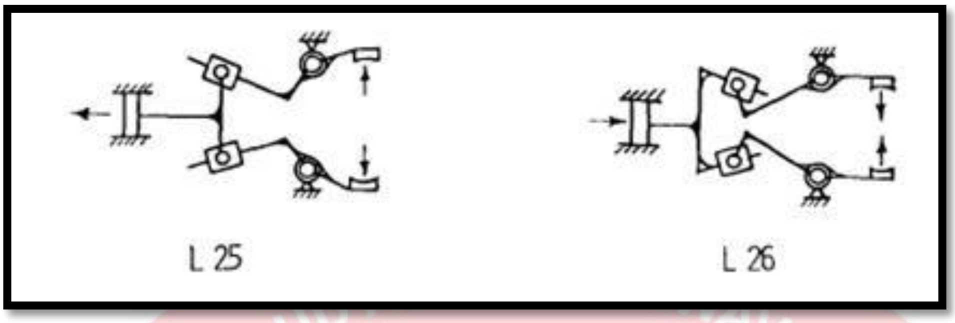
Finally, I needed to design my pressure gripper with a translation movement and I had a lot of possibilities and designs to do, so I selected some of the designs that I saw and I use as prototypes for my gripper's design. These are some of these designs:



[5] – Six different gripper with translation movement.

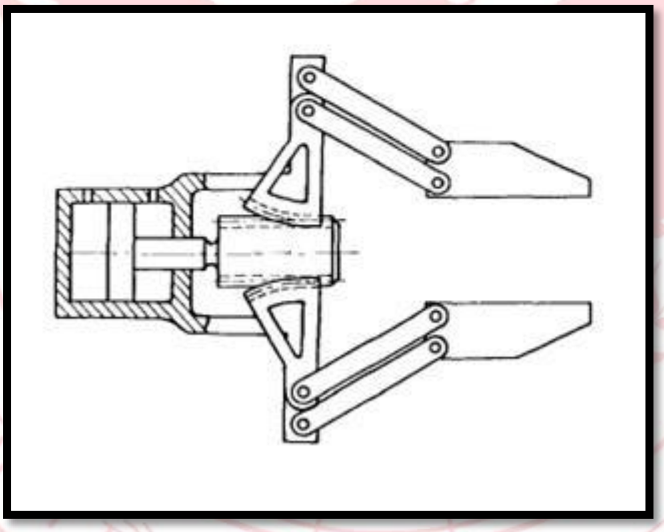
As you can see [5] there are a lot of types of grippers. In addition, the translation movement grippers are classified in other groups according to the mechanism used to move the gripper:

1. **Linkage Grippers:** there is no cam, screw, gear. There is movement only because of links attached to input and output. There must be perfect design of mechanism such that input actuator's motion is transformed into the gripping action at the output.



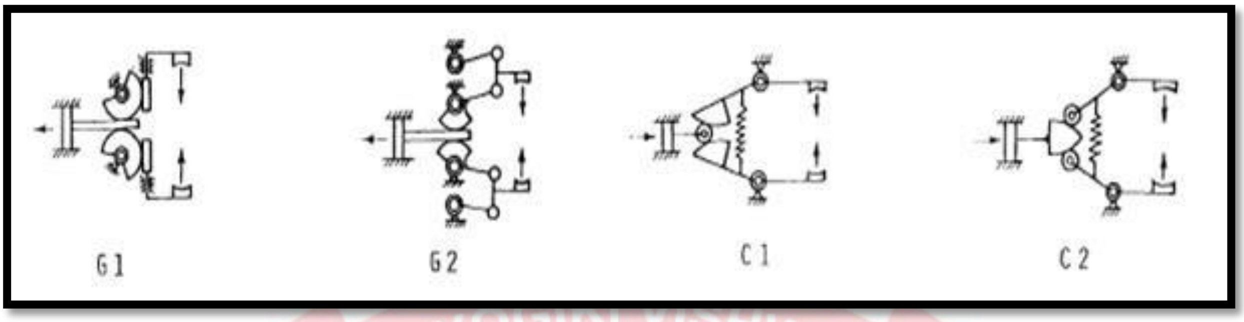
[6] – Example s of two linkage grippers

2. **Gear and Rack Grippers:** movement of input due to gear motion which makes connecting links to go in motion to make gripping action at the output link.



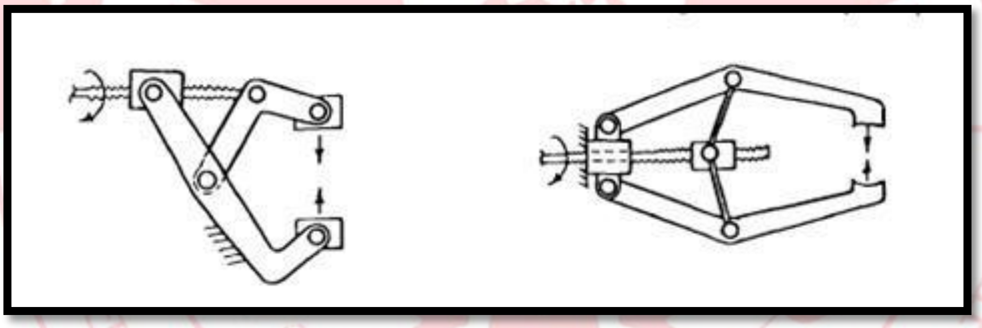
[7] – Gear gripper with the motion in the middle

3. **Cam-actuated Grippers:** reciprocating motion of the cam imparts motion to the follower, thus causing fingers to produce a grabbing action. A variety of cam profiles can be employed- constant velocity, circular arcs, harmonic curves etc. This mechanism is similar that the linkage gripper but in this intervene the cams.



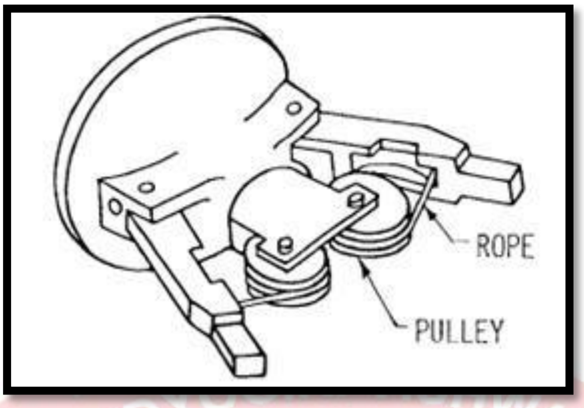
[8] – Four different examples of cam-actuated grippers

4. **Screw-driven Grippers:** operated by turning screw, in turn giving motion to connecting links and thus giving griping motion to output. Screw motion can be controlled by motor attached.



[9] – Examples of screw -driven grippers

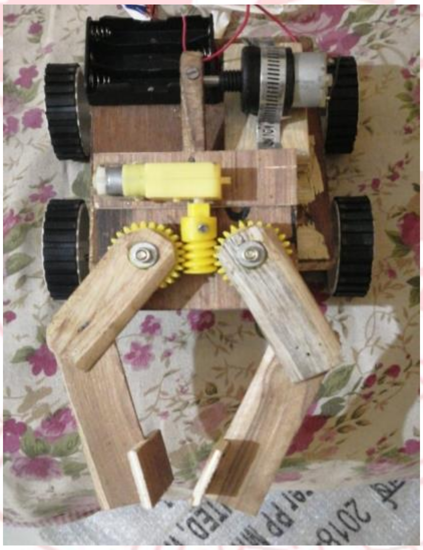
5. **Rope & Pulley Grippers:** motor attached to the pulley makes the winding and unwinding motion of rope in turn it set gripper action into motion via connecting link.



[10] _ Rope and pulley gripper

I selected the **gear gripper** because I thought that it was the cheapest way and it was very practical and easy to build.

After all of these choices, our final design of the gripper was the next:



we had to take another decision before finishing my design. We decided to use only **one gripper ("one finger")** instead of two or more fingers with the goal of saving material and doing the robot's gripper as cheap as possible.

STATE OF ART

Before starting with the design of the new module, the related work is reviewed in order to find out what is being used at the moment to grasp objects. The grippers will be categorized in three main groups: industrials, hobby or leisure and others.

Industrial grippers

- Adaptive robot gripper

Used in industrial applications, they have two or three fingers with two degrees of freedom. They are compatible with all major industrial manufacturers and enable you to manipulate a wide variety of objects. They are designed to facilitate part ejection and part seating. Some applications are machine tending, collaborative robots and assembly.

  - 2-FINGER 85 (3)

Although it can grasp a large variety of objects, it is perfect for items with two parallel faces or cylindrical ones using its encompassing mode due to its two degrees of freedom.

Figure : Adaptive robot gripper 2-FINGER 85

2-FINGER 200 (3)

With a stroke of 200 mm and a payload of 23 kg, this sealed and programmable Robot Gripper can handle a wide variety of parts. The main differences with the previous one is that it can also grasp objects from inside a hole and the objects can be much heavier.

Figure : Adaptive robot gripper, 2-FINGER 200

- 3-FINGER (3)

Provides hand-like capabilities to the robots and it has reliability in unstructured environments. It is suitable for R&D projects although it is also used in various industrial applications. It is designed for advanced manipulation tasks.

Figure : Adaptive robot gripper, 3-FINGER

- Pneumatic grippers

AGI pneumatic grippers have a wide range of sizes, jaw styles, and gripping forces for almost any industrial application. The three major types of pneumatic grippers are parallel gripper, angular gripper, and custom units such as O-ring assembly machines. These products are used in various industries such as Aerospace, Automotive, Appliance, automated industrial O-ring systems, Electronic, Medical and Packaging.

- Compact Low Profile Parallel Gripper (4)

It is ideal for small parts handling. It has long stroke and light weight designed for robotic applications where weight is an issue.

Figure : Pneumatic grippers, compact low profile

Single Jaw Parallel Gripper - One Fixed Jaw Style (4)

It is made for use in tight spaces needing large payloads. It is ideal for situations where the zero position of one jaw is need. This gripper has a T-slot bearing design that is supported the length of the body to carry heavy loads.

Figure :Pneumatic grippers, Single jaw parallel

- Dual Motion Gripper (4)

Automated seal and O-ring assembly made for small to large O-ring or part pick and seat applications. Spread and place seals with these dual motion automatic O-ring placement assembly machine. It is designed to facilitate part ejection and part seating.

Figure : Pneumatic grippers, dual motion

Hobby or leisure

- Bioloid gripper

Bioloid is an educational robot kit which who you can learn the basic of structures and principles of robot joints and expand its application to the creative engineering, inverse kinematic, and kinetics. It is also for hobbyists who enjoy building customized robots.

- Simplest model (5)

A gripper can be easily assembled with two metal frames and one single servo. In this case one of the frames is directly fastened to the servo case and only the second one is moving. It is mainly useful for large objects.

Figure : Simplest model of bioloid gripper

AX-12 Dual Robotic Gripper (6)

This robotic arm gripper design is ideal for a numerous robotic arm manipulation tasks that can be applied to all types of shapes. The two servos can move synchronously having one degree of freedom or independently having two degrees of freedom.

Figure : Bioloid gripper with two servos

- Lego Mindstorms gripper

Lego Mindstorms is a kit that contains software and hardware to create customizable, programmable robots. They include an intelligent brick computer that controls the system, some modular sensors, motors and Lego parts to create the mechanical systems. Its application is mainly educational. There are two versions: NXT is the first one and the second one is EV3 with the same characteristics but more powerful and with larger variety of sensors.

- NXT simple gripper (7)

With some Lego parts, some gears and a single motor, an angular gripper can be assembled without big difficulties.

Figure : NXT simple gripper

- NXT crane (8)

With the same NXT kit much more complex grippers can be assembled. This one not only can close and open the gripper but also position it in the right place. It also has an infrared sensor to detect if an object is ready to be grasped.

Figure : NXT gripper in crane

- EV3: GRIPP3R (9)

Using EV3, the more powerful version of Lego Mindstorms, a wheeled robot as this one can be built. The GRIPP3R robot is constructed for some heavy-duty lifting. It has got the muscle to grab and drop a can of soda with its powerful grasping grippers.

Figure : EV3 gripper robot

Others

- Universal gripper (10)

The universal robotic gripper is based on the jamming of granular material. Individual fingers are replaced by a single mass of granular material that, when pressed onto a target object, flows around it and conforms to its shape. Upon application of a vacuum the granular material contracts and hardens quickly to pinch and hold the object without requiring sensory feedback.

Figure : Universal gripper with granular material

- Makeblock robot gripper (11)

It is made from a heavy duty but lightweight PVC and it has extra anti-slip material on the inside of two fingers. It comes with four standard M4 thread holes on the bottom for easy assembly to any other robot.

Figure : Makeblock gripper

STUDY AND ANALYSIS OF MOTION

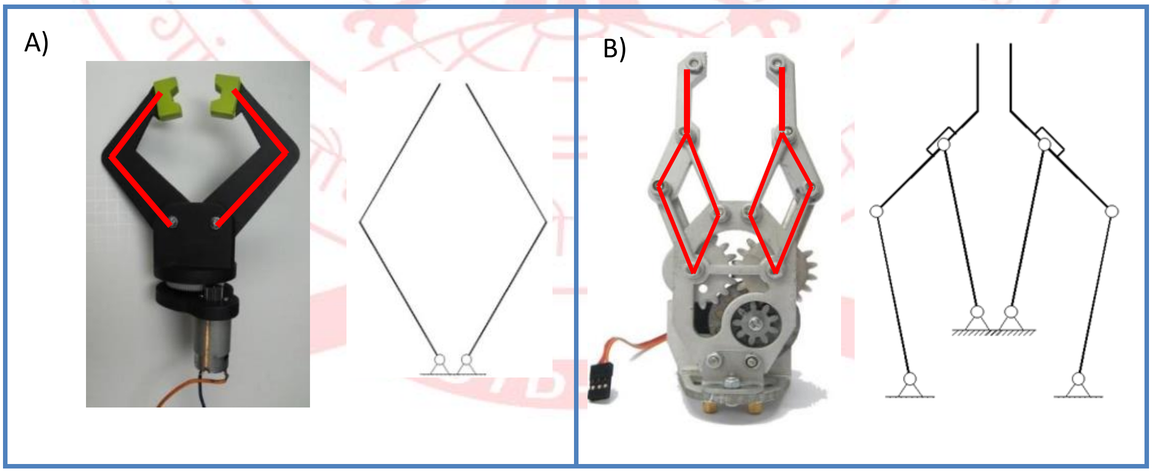
Study of the motion of some mechanisms

In order to choose the design of the best mechanism for the purpose of the project, it is necessary to study the different possibilities.

The study consists of a first simplification of the grip to the kinematic chain using the program PAM (12). All the simplified designs are exactly the same size to be able to make a reliably comparison of the results afterwards. Then the grasping action is simulated and the displacement and forces plotted. In all the following grippers, a rotational motor has been considered for each degree of freedom of each finger but with symmetric movement for the two fingers. The grippers simulated can be divided in two main groups depending on the degrees of freedom that they have.

One degree of freedom

Following the classification of the kinematics chain, three types of grippers can be found. The rotational motion is option A (13). In parallel motion two possibilities are contemplated: using a parallelogram that will remain its sites always parallel two by two that is option B (14) and a movement with a guide that ensures the parallelism and restrict not only the rotation of the jaws but also their vertical motion, option C (15). Finally a combination of rotation and translation is shown as planar motion is option D (16). (See Figure 19)



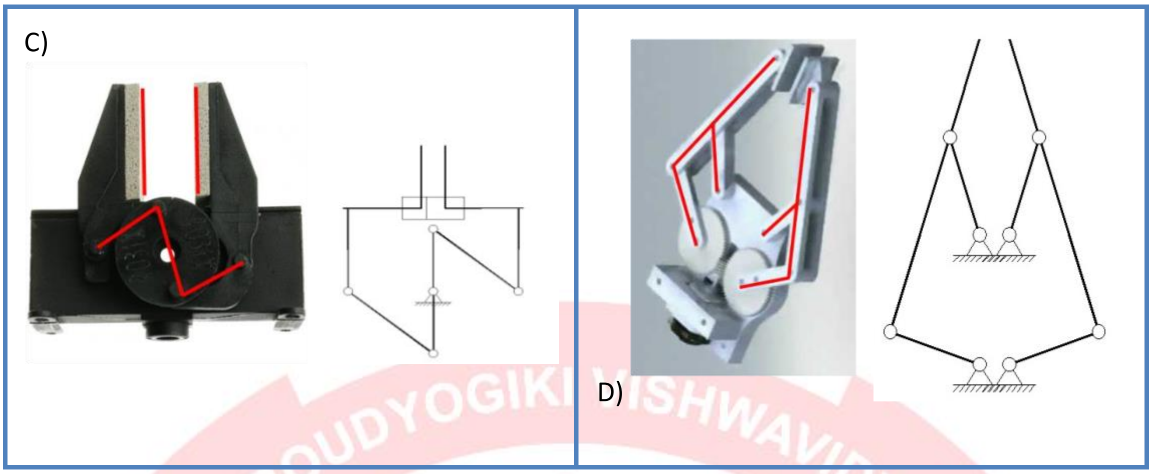


Figure : Grippers examples of one degree of freedom and simplifications. Top-left is angular, top-right is parallel with a parallelogram, bottom-left parallel with a guide and bottom-right is planar motion

Every mechanism is simulated by rotating one radian the actuator from the maximum opening to its closure holding a 1 cm object. This way it is obtained the stroke curve that shows, for each position of the motor, the position and orientation of the left jaw, knowing that the right one has a symmetrical motion. Its function is to control the jaws motion from the actuator motion and it is illustrated in Figure 21. Obviously, in option B and C the jaws do not have any rotation and it can be seen that the maximum jaw horizontally displacement is achieved in option A, the angular motion.

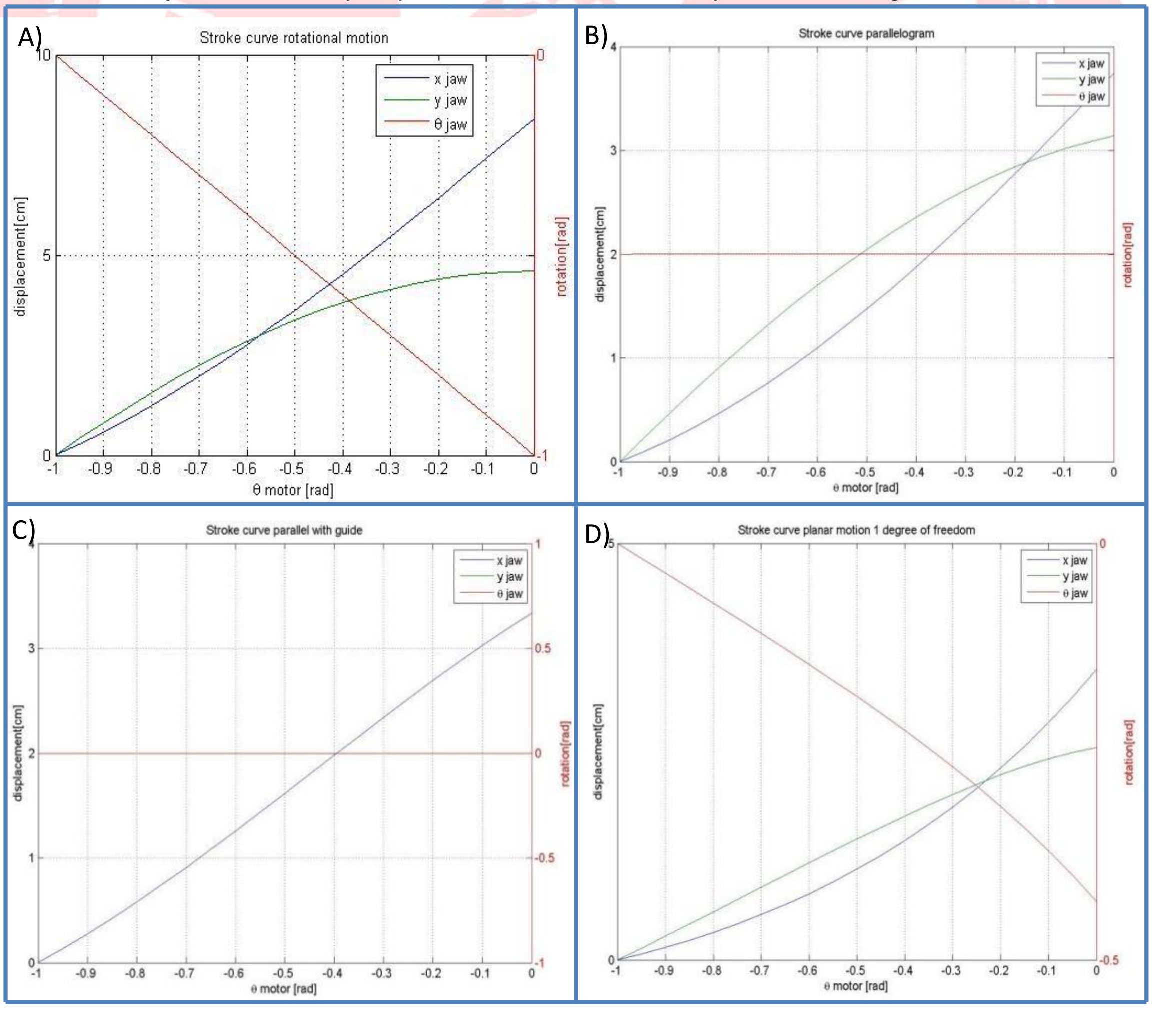


Figure : Force curve of the four mechanisms

To compare the torque that is needed in each of the mechanisms previously mentioned, 1N has been horizontally applied to each jaw during the simulation. The torque that the actuator needs to do in each position of the motor is plotted in Figure 20, knowing that each position of the motor is equivalent to a size of the object grasped. For the simulation one actuator has been placed in each finger so in case of using just one motor the torque would be twice the one in the graph. It is important to take into consideration that, as the force applied in the jaws and

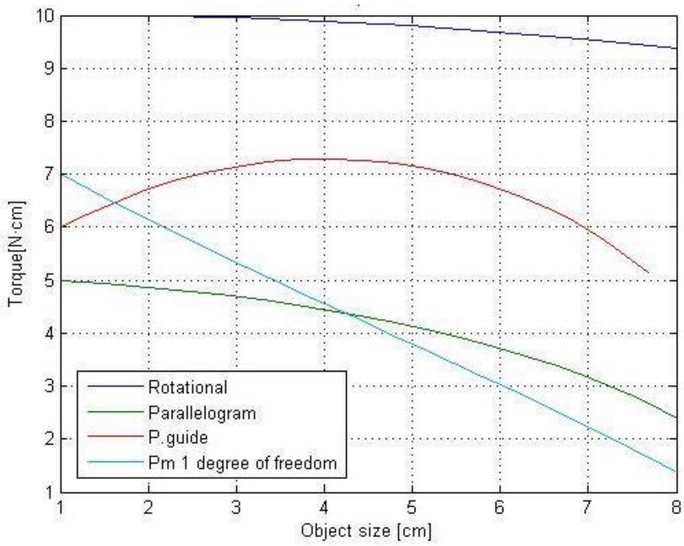


Figure : Stroke curves of the four mechanisms

the torque needed are linearly dependents, by multiplying the force curve per the real grasping force, the real torque is obtained. It can be seen that the rotational (option A) one requires an enormous torque and the ones which need a lower torque are the parallel using a parallelogram (option B) and the planar motion of 1 degree of freedom (option D).

Two degree of freedom

The complexity of the mechanisms can increase as much as wanted. In the case of two degrees of freedom a wide variety of motions can be achieved from parallel motion to an enclosing one. The motion depends on the relation between the speeds of the two actuators as well as the initial position of both of them. It is also possible to control one of the degrees of freedom with the motor and live the second one free to allow the gripper to adapt to the object shape.

Figure 22: Example of a two degrees of freedom gripper (3)

In order to compare this mechanism with the previous ones, two motions have been simulated and its stroke curve as well as its force curve is illustrated in Figure 23. The graphs on the left correspond to a parallel motion and the ones on the right to an encompassing motion.

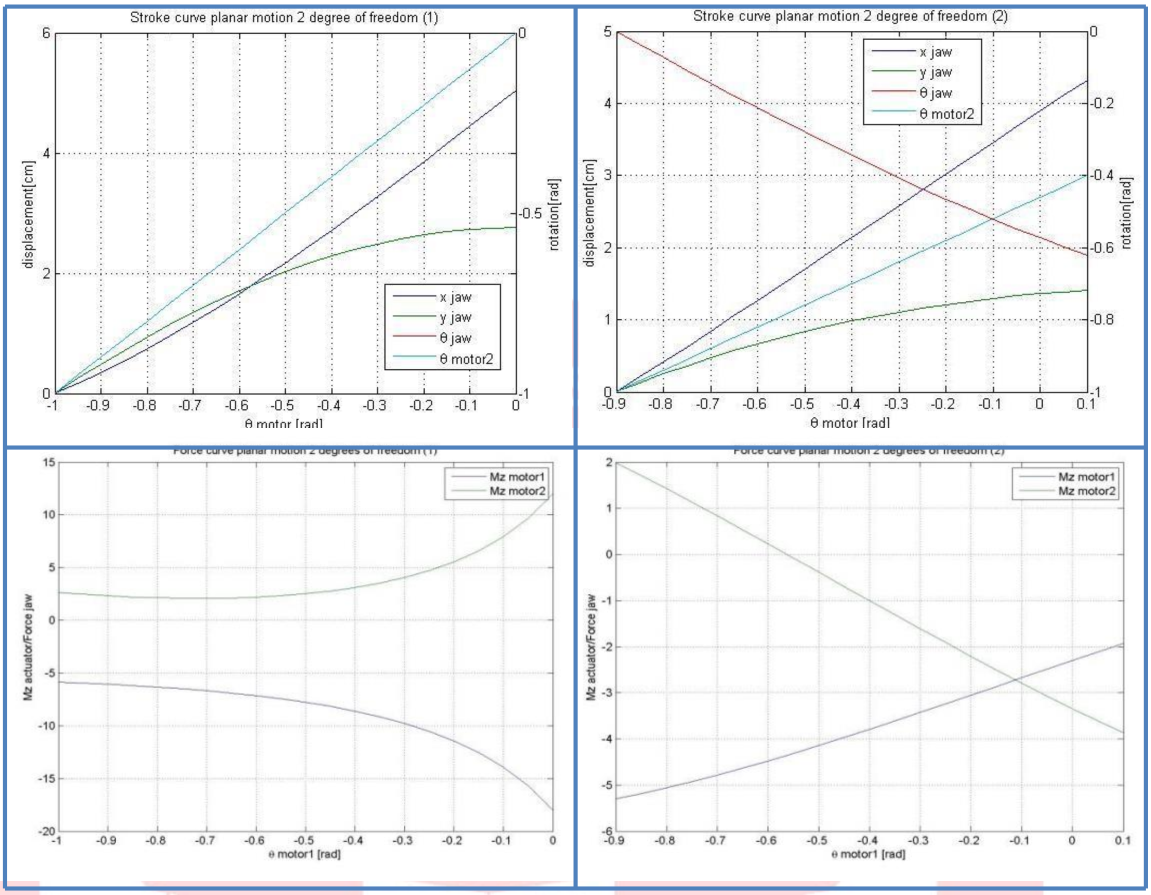


Figure : Top: stroke curve of parallel motion (left) and encompassin (right); bottom: force curve of parallel motion (left) and encompassin (right)

In the stroke curve can also be found the rotation of the second motor that is needed in order to achieve the desired movement of the jaws. In the force curve each line represents one actuator. In the parallel motion, it is shown that more than 10 $N \cdot cm$ and 15 $N \cdot cm$ are needed on the two motors just to hold the item with 1 N force. On the other hand, in the encompassing option less than 6 $N \cdot cm$ are required. Both motions are depicted in Figure 24 from (17).

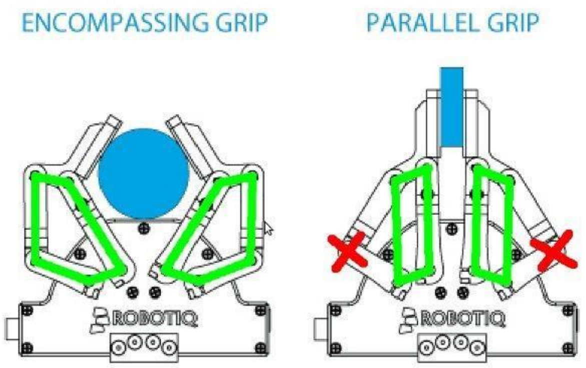


Figure : Encomapssing mode and parallel mode in the two degrees of freedom gripper

Discussion of the simulations

Once all the mechanisms have been simulated they can be compared in order to choose the one that fits better for the Fable's gripper. The decision will be made focusing on the stroke of the mechanism to ensure that all the objects can be gasped; the torque that is actually transmitted from the actuator to the jaws and finally the building simplicity of the mechanism. For that purpose, the results of the simulations are summarized in the Figure 25. In the first place it contains the size of the biggest object that can be grasped calculated from the horizontal jaws position. Secondly the torque range that is required in the actuator during the simulation of a rotation of 1 radian. Thirdly, to compare the torque's needs of all the mechanisms in the same position, the torque needed when holding a beverage can with a diameter of 6.63 cm (18) is also in the following table.

Type	A) Rotational	Parallel		D) Planar 1 DOF	Planar 2 DOF	
		B) Parallelogram	**C) Guide**		**Parallel**	**Other**
Max object size [cm]	17.8	8.4	7.6	8	11	9.6
Torque range [N·cm]	[5.4, 10]	[1.9, 5]	[1.4, 7]	[1.4, 7]	[5.9, 18] (motor1)	[1.9, 5.3] (motor1)
					[2.6, 12] (motor2)	[0, 3.9] (motor2)
Can torque [N·cm]	9.55	3.38	6.37	2.51	7.8 (motor1)	3.4 (motor1)
					2.5 (motor2)	1.6 (motor2)

Figure : Table of the summmarized results of the simulations

About the one degree of freedom, it can be seen that, although the rotational option is the one that can grasp the biggest object is also the one that needs the highest torque so it can be definitely discarded. Secondly the parallel motion using a guide is not useful neither because it has the smaller stroke and such a big torque. The remaining options would be B and D.

When comparing them to the mechanism of two degrees of freedom, it can be seen that the benefits in the stroke and torque are not gigantic but it is more about its flexibility of movements. On the other hand this flexibility implies an increase in the building, design and control difficulty.

CONTROL OF GRIPPER

Once the mechanic design has been completed the next step is to control its motion to achieve the griping task. Also it is useful to control the amount of torque that it is doing to ensure that the surface of the grasped object is not being damaged.

5.1. Distance measure (22)

In order to assist the gasping action, for example programming that the gripper closes automatically when the object is in the right position, a distance sensor is required. It is placed between the two fingers at the end of the shell. There are two possibilities for measuring the short distances: infrared sensors (IR) and ultrasonic sensors (US). To choose the best one, it is needed to know how they work.

- Infrared sensor

The infrared sensors can be used in several applications and one of them is short distance measurements. The most extended IR sensors for this purpose are called SHARP (See Figure 45).

Figure : Example of SHARP IR sensor

There are two major types of Sharp's infrared sensors based on their output: analog rangers and digital detectors. The first ones provide information about the distance to an object in the ranger's view. Digital detectors provide a high or low indication of an object whether if it is closer than a predefined distance or not.

These sensors use triangulation and a small linear CCD array to compute the distance or presence of objects in the field of view. In order to triangulate, a pulse of IR light is emitted by the emitter. The light travels out into the field of view and either hits an object not. In the case of no object, the reading shows that no light is reflected. If the light reflects off an object, it returns to the detector and creates a triangle between the point of reflection, the emitter and the detector as it is shown in Figure 46.

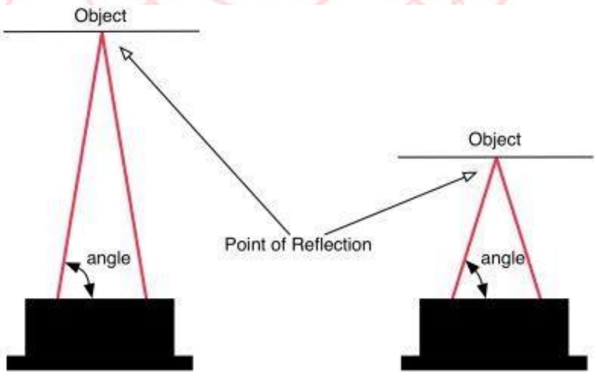


Figure 46: Distance measurement of IR sensors

The incident angle of the reflected light varies depending on the distance from the sensor to the object. The receiver led of the IR sensor is a precision lens that transmits reflected light onto various portions of the enclosed linear CCD array. The CCD array can then determine the incident angle, and thus calculate the distance to the object. This method of ranging is very immune to interference from ambient light and it is not affected by the color of the object that is being detected.

- Ultrasonic sensor

The ultrasonic sensor (see Figure 47) radiates a sound pulse signal to the object and then receives a reflection sound signal (“echo”), back to sensor. The distance will be measured by calculating the reflection time interval between the target and sensor. Its actuating mechanism is illustrated in Figure 48.

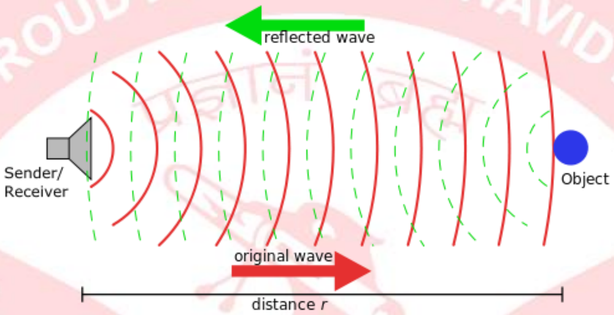


Figure : Example of ultrasonic sensor

Figure Distance measurement of ultrasonic senors

Ultrasonic sensing technology is based on the principle that sound has a relatively constant velocity. The time for an ultrasonic sensor's beam to strike the target and return is directly proportional to the distance to the object.

- Comparison (23)

Usually the ultrasonic sensors are more useful for larger distances than the infrared and in this case the minimum distance that should be measured is approximately 5 cm so it seems that IR will work better. In the table Figure 49 are summarized some specifications of the most extended two commercialized sensors. As said the IR measure shorter distances with better resolution but the most important thing is the beam width.

Sensor	MaxSonar LV EZ1	Sharp GP2Y0A02YK0F
Range	0.15 – 6.45m	0.2-1.5m
Resolution	2.54cm	1cm
Beam Width	± 30º	10º
Weight	4.3g	4.8g

Figure 49: Comparison table of ultrasonic and IR sensors

The sensor will be placed in the middle of the fingers it is essential not to detect them as if they were a grasping object. That is why the smaller beam width turns IR the best option. (See Figure 50).

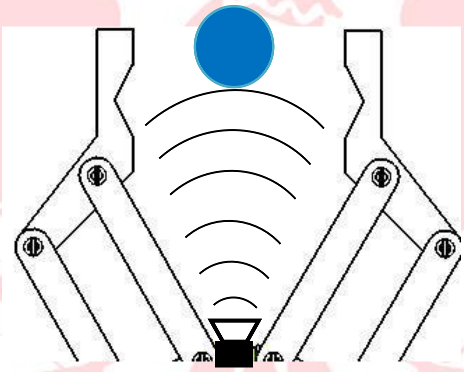


Figure : Distance sensor placed between the fingers

Once the IR has been chosen as the most suitable option, the different types of SHARPS are represented in Figure 51 and they mainly differ in the scope of vision.

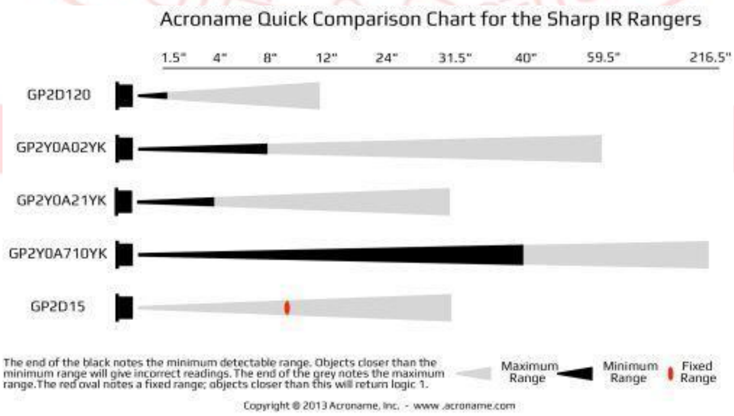


Figure : Comparison of the types of SHARP

They all have the minimum distance from where they start being effective and the maximum one that can discern, from there on non-object is detected. This two distances can be understood looking the output distance characteristics of Figure 52 where the result is not reliable before the peak of the curve. Although the GP2D120 would be more suitable, the GP2Y0A02 is being used because of availability issues and its datasheet can be found in the annex CD.

The read output of this sensor goes from aproximately 40 points when nothing is detected until aproximately 650 points when the object is 10 cm far from the sensor. Then the output value decreases again. The problem is that if the value is for example 400, there are two possible distances one before 10 cm and one after 10 cm and the user must know which one is it. Usually to avoid this problem the shorter distance sensor would be used but it can also be used if paying attention to this fact.

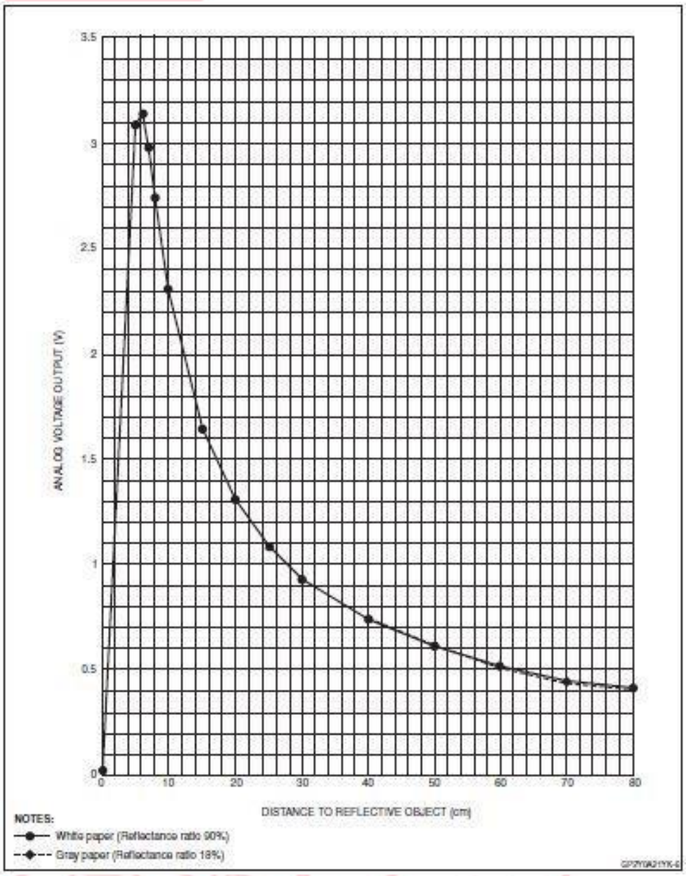


Figure : Output distance of Sharp GP2Y0A02YK

General Discussions

At this point, it can be said that the gripper has achieved its main purpose of grasping the ten objects with a great success, up to 97%. However, there are several improvements that need to be included in the future development, mostly to decrease the price and volume of the gripper.

After a depth study of the types of grippers that exist, the simulations of different mechanisms have been vital to choose the best design of one degree of freedom. It also leaves an open door to investigate whether the benefits of two degrees of freedom outweigh its building and controlling complexity.

Reviewing the requirements, the maximum distance between the jaws has always been the right one as well as the two points of contact to ensure the right stability. The closed housing and the incorporation of Fable's connectors system have been achieved in the second prototype. The distance to the object and force control is also included in the second prototype but without the accuracy that it should. The injection modeling, price and robustness requirements are more focused on the final version and they cannot be ensured yet but the three of them are likely to be accomplished without difficulties.

The iterative manner of designing has been really useful to first focus on the gripper mechanism design and the drive chain and only once seen that they were properly working, then think about the housing and sensors.

The next modifications that the gripper should face are in the first place changing the screws and nuts that perform as axis of the mechanism for a better option. In the second place using a more suitable IR sensor or even build it with two diodes because it would be smaller and cheaper although probably more difficult to control. And thirdly changing the servomotor to another smaller and cheaper but with the same or ever bigger torque capacity. It would be useful to choose a servomotor with force control included but this is also something that could be built separately.

As the experiments showed that the most difficult objects to grasp are the non-deformable and non-cylindrical a new jaw design could also be considered using a softer material to increase the contact area.

Finally, in order to be a real Fable system module it definitely needs to include the electronics inside the shield and also enable the wireless communication by radio. For that purpose it needs to change the CM-510 controller to a smaller board.

When all these modifications are applied the prototype will be extremely close to the final version.

TESTS

The experimentation will go through the four tests as follows. In the results table of each test there are the three replicas and the average of every grasping type for each object and also a last column with the total average of each object and the sum of them provides a grade from 0 to 10 of how successful the test has been.

Test 1

The first prototype is connected to the controller and to the computer and the program *1.MANUAL* that can be found on the attached CD is loaded.

The first object is manually located between the jaws as explained before and with the L button the jaws are closed until the object is subjected. If after two seconds the object is still held with the gripper, it can now be opened with the R button and the attempt is passed so the result is 1, otherwise the attempt is failed and the result is 0.

This sequence is repeated is repeated with the ten objects Then objects are grasped in their fixed order and the results are written down in the table. Then the ten objects are grasped again in normal grasping manner in the same order and then a third time. Finally the average of the three replicas is calculated.

The same procedure is done with misalignment and rotation. All the results are summarized in the table from Figure.

TEST 1	Normal grasping				Misaligned grasping				Rotation				TOTAL
0. Plastic bottle	1	1	1	1		1	1	1		1	1	1	1
1. Can	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Egg	1	1	0	0,667		0	1	0,333		1	0	0,333	0,444
3. Shoe	1	1	1	1	1	1	1	1	1	1	0	0,667	0,889
4. Orange	1	1	1	1		1	1	1		1	1	1	1
5. Box	1	1	1	1	1	1	1	1	1	1	1	1	1
6. Fable's brick	1	1	1	1		1	0	0,667		0	1	0,667	0,778
7. Cup	1	1	1	1	1	0	1	0,667	1	1	1	1	0,889
8. Marker	1	1	1	1		1	1	1		1	1	1	1
9. Teddy													

	1	1	1	1	1	1	1	1	1	1	1	1	1
													9

Figure : Table with the results of the test 1

Test 2

The second prototype is now connected to the controller and to the computer and the same program *1.MANUAL* from the CD is used.

The procedure is exactly the same as in test 1 and the results are in the Figure.

TEST 2	Normal grasping				Misaligned grasping				Rotation				
0. Plastic bottle	1	1	1	1	1	1	1	1		1	1	1	1
1. Can	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Egg	1	1	1	1		1	0	0,667		1	1	0,667	0,778
3. Shoe	1	1	1	1	1	1	1	1	1	1	1	1	1
4. Orange	1	1	1	1		1	1	1		1	1	1	1
5. Box	1	1	1	1	1	1	1	1	1	1	1	1	1
6. Fable's brick	1	1	1	1		0	1	0,667		1	1	1	0,889
7. Cup	1	1	1	1	1	1	1	1	1	1	1	1	1
8. Marker	1	1	1	1		1	1	1		1	1	1	1
9. Teddy	1	1	1	1	1	1	1	1	1	1	1	1	1
													9,667

Figure : Table with the results of test 2

Test 3

The second prototype is again connected to the controller and the computer and the program *2. GENERALLY AUTOMATED* is loaded.

The first object is normally approached to the griper from the top and the IR sensor is calculating the distance to it. When the object is located between the fingers they are start closing and the user has to manually place the object in the right position centered in the jaws. If it is held after two seconds the attempt is passed, the program must be reinitialized and the second object can proceed.

Again the ten objects are orderly grasped three times in each grasping mode and the results are in Figure.

TEST 3	Normal grasping				Misaligned grasping				Rotation				
0. Plastic bottle	1	1	1	1		1	1	1		1	1	1	1
1. Can	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Egg	0	0	1	0,333		0	0	0		0	1	0,333	0,222
3. Shoe	1	1	1	1	1	1	1	1	1	1	1	1	1
4. Orange	1	1	1	1		1	1	1		1	1	1	1
5. Box	1	1	0	0,667	1	0	0	0,333	1	1	0	0,667	0,556
6. Fable's brick	0	1	1	0,667		0	0	0,333		1	1	0,667	0,556
7. Cup	0	0	1	0,333	0	1	0	0,333	0	0	0	0	0,222
8. Marker	1	1	1	1		1	1	1		1	1	1	1
9. Teddy	1	1	1	1	1	1	1	1	1	1	1	1	1
													7,556

Figure 65: Table with the results of test 3

Test 4

For the last test, the second prototype is also used. It is connected to the cm-510 and to the computer the program *3.PARTICULARLY AUTOMATED* is loaded.

When it is executed the fingers go to the open position, then one number is introduced by Serial in order to adjust the parameters of distance to the sensor and goal position of the motor to its right value for that particular item.

The object needs then to slowly approach the gripper from the top until all the LEDs are turned on to show that the distance to IR has been achieved and then remain in that position while the fingers grasp it. When any letter is introduced by Serial the gripper will opens again and it will be ready for the next attempt.

With this procedure the test is executed starting with normal grasping, misaligned and the rotation one and all the results are in Figure .

TEST 4	Normal grasping				Misaligned grasping				Rotation				
0. Plastic bottle	1	1	1	1		0	1	0,667		1	1	1	0,889
1. Can	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Egg	0	0	1	0,333		0	0	0		1	1	1	0,444
3. Shoe	0	1	1	0,667	1	1	0	0,667	0	1	1	0,667	0,667

4. Orange	1	0	1		0,667		1	1	1		0	1	0,667	0,778
5. Box	0	1		1	0,667	1	0	0	0,333	0	0	1	0,333	0,444
6. Fable's brick	1	1	0		0,667		0	0	0,333		1	0	0,333	0,444
7. Cup	0	0		0	0	0	0	0	0	0	0	0	0	0
8. Marker	1	1	1		1		0	1	0,333		1	1	1	0,778
9. Teddy	1	1		1	1	1	1	1	1	1	1	1	1	1
														6,444

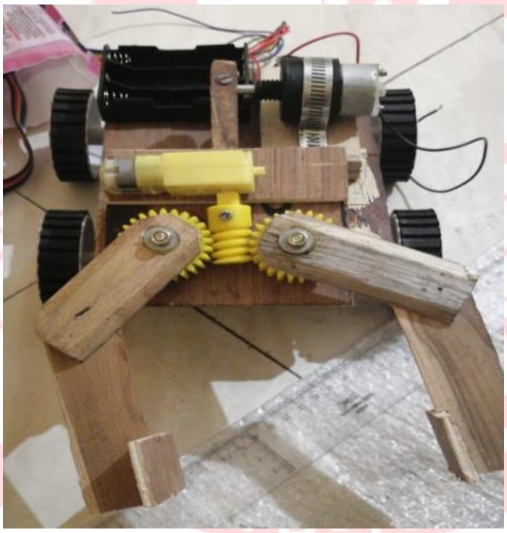
Figure Table with the results of test 4

RESULT

In this section we are going to see the final and real result of the gripper. I’m going to add a photo of the real assembly of the gripper and one table with the time of printing of every piece and the number of layers. With this real gripper we are able to calculate the real forces and we can compare it with the theoretical forces calculated in the project.

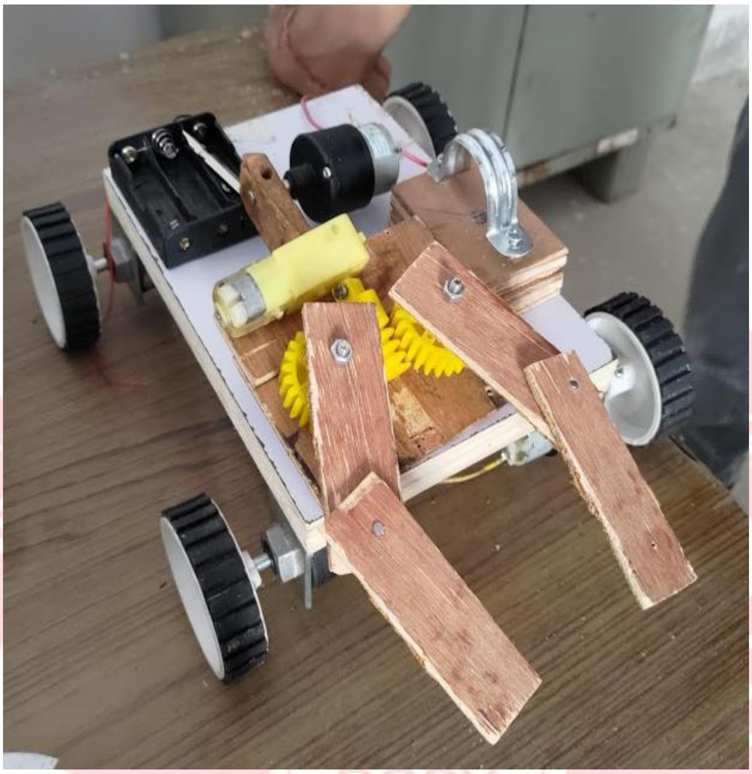
Real aspect of the gripper

We can observe in the image the final aspect of the gripper. This is very similar to the 3D model so we can say that the project has been very satisfactory.



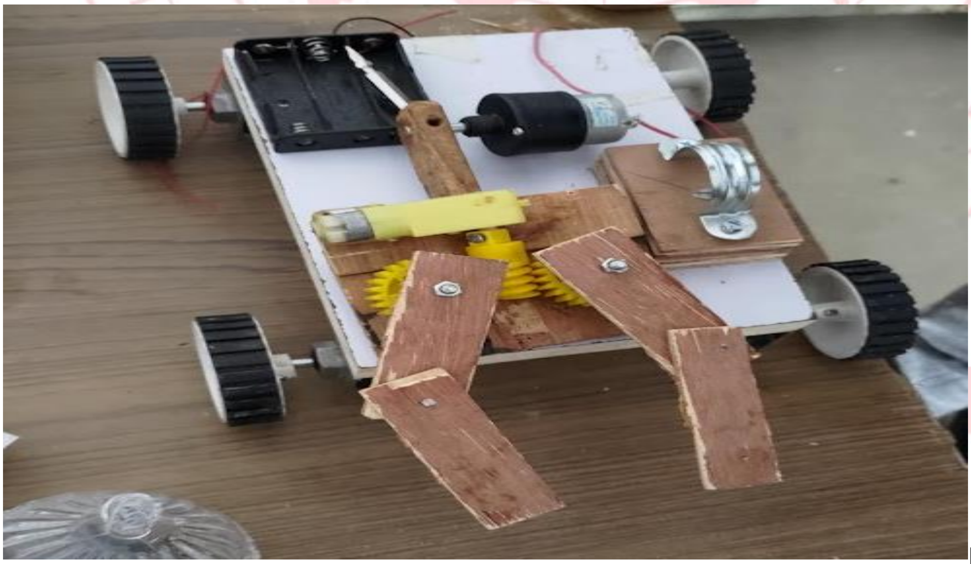
Picture of the real aspect of the gripper

Minimum aperture:



Picture of the real gripper with the minimum aperture

Maximum aperture



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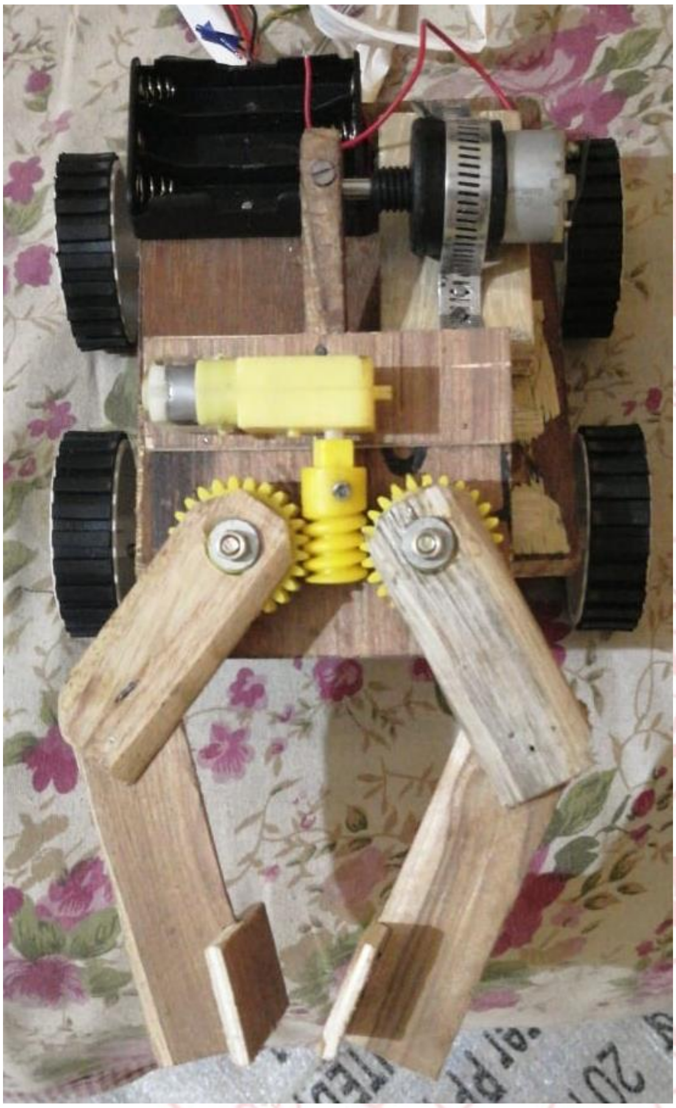
Picture of the real gripper with the maximum aperture

Frontal view



We can observe that the real front view of the robot's gripper is similar to the 3D model front view, so we can conclude that the project is a success.

In this part, I'm going to write some international standards of security of the robots and some security measures which everyone have to comply when is designing a robot.

The most important standard before building the Robot are the following:

- *International standard ISO 10218:1992*

It is a standard made by the international agency Standardization [ISO92]. It is relatively recent, dating from 1992. Roughly contains the following information: a section on safety analysis, the definition of risks and identifying possible sources of hazards or accidents. It also contains a section on design and manufacturing, which devotes a brief analysis to the design of robotic systems, considering mechanical, ergonomic and control aspects.

American standard ANSI/RIA R15.06-1992.

It is a policy conducted by the National Institute of US Standardization (ANSI) [ANSI-92]. Also dating from 1992, and a review of the regulations published in 1986. It is relatively short. But it has some features that deserve stand. For example, the inclusion in the section on the definition of risks of some sections that deal with the probability of occurrence of an accident and the severity of the possible physical harm to a person, dependent on operator experience level and frequency in which it is in the danger zone.

European standard EN 775

The European Committee for Standardization (CEN) approved in 1992 the Standard EN 775, the intentional adaptation of ISO 10218:1992.

Most important security measures are the following:

- **Limit determination system:** intended use, space and working times, etc.
- **Identification and description of all hazards** that may generate the machine during the working phases. Should be included risks arising from a joint effort between the machine and the Computer and risks arising from misuse of the machine.
- **Defining the risk of accident.** It is defined probabilistically depending on the physical damage that may occur.
- **Check** that **the security measures** are adequate.

CONCLUSIONS

The results of the experiments can be evaluated separately test by test and object by object. However, the most interesting thing is to compare the different tests to see what have changed between the first and the second prototype as well as the differences between the three programs.

- Success of each test

Focusing on the general punctuation of each test it can be seen that the test with a higher punctuation is the second one with a 9.7 and it corresponds to the second prototype and manually mode. The second one with a slightly lower grade is also manual but first prototype, test 1 with a 9. Test 3 and 4 are quiet far from the others with a punctuation of 7.5 and 6.4. In any case, all of the tests have had a satisfactory result.

- Success of each object

About the objects, the most difficult to be grasped has been the egg, it has only passed 47% of attempts. The second one is the cup with passed the 53% of attempts and the third one the Fable’s brick with a 67% of success. The main reason seems to be that they are completely nondeformable so the contact surface is very small. On the contrary, the teddy has been grasped the 100% of the attempts and its deformability is obvious.

- Comparison of test 1 and 2: prototypes changes.

The two prototypes have only two differences when using the manual mode. The new design of the jaws is the main change suffered in the second one but also it has been taken into consideration the loss of material when laser cutting the gears. These developments are reflected in the results but the change is only a 7% of improvement.

- Comparison of test 2, 3 and 4: programming changes

The main difference between the three programs is how much the user interferes in the control of the grasping action and how much is automated. It can clearly be seen that the best one is when everything is under the user control.

When the IR sensor acts, the results have worsened in a 15% so this is something to continue working on. Probably with the most suitable senor, the automated control would be better. Between test 3 and test 4 the difference is not that big but again it works better the one that is not totally automated and the user is responsible of part of the control.

- Building complexity

Although the two prototypes have more or less the same pieces, the assembly time is almost triple in the second one. This can be explained because inside the shield the access is more difficult and it takes more time and also in the second prototype everything is better subjected than in the first one.

- Price

The second prototype is clearly more expensive than the first one but it must be taken into consideration that it includes the IR sensor and a shield to cover the drive chain. Also this price has nothing to do with the expected for the final version because the 3D printing and laser cut are much more expensive than injection modeling when a large number of items are made.

Future Scope

At the beginning of this project some main goals and secondary goals were settled. All of those goals have been fulfilled:

- We have achieved the main goal that is the design and manufacturing and construction of a robot’s gripper.
- We have designed one robot’s gripper with a good structure to insert improvements and changes and it’s a good chance for other people who like this kind of projects to start a new design with this one as base.
- Personally, I have learnt a lot with this project, especially, about the robotics and printing 3D world. I have discovered that the robotics world is going to be, probably, a very important area in the future and it can help in a lot of industrial processes.

As final conclusion, I would like to say that all the process of the project has been a success so I’m very satisfied with this.

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